DETR
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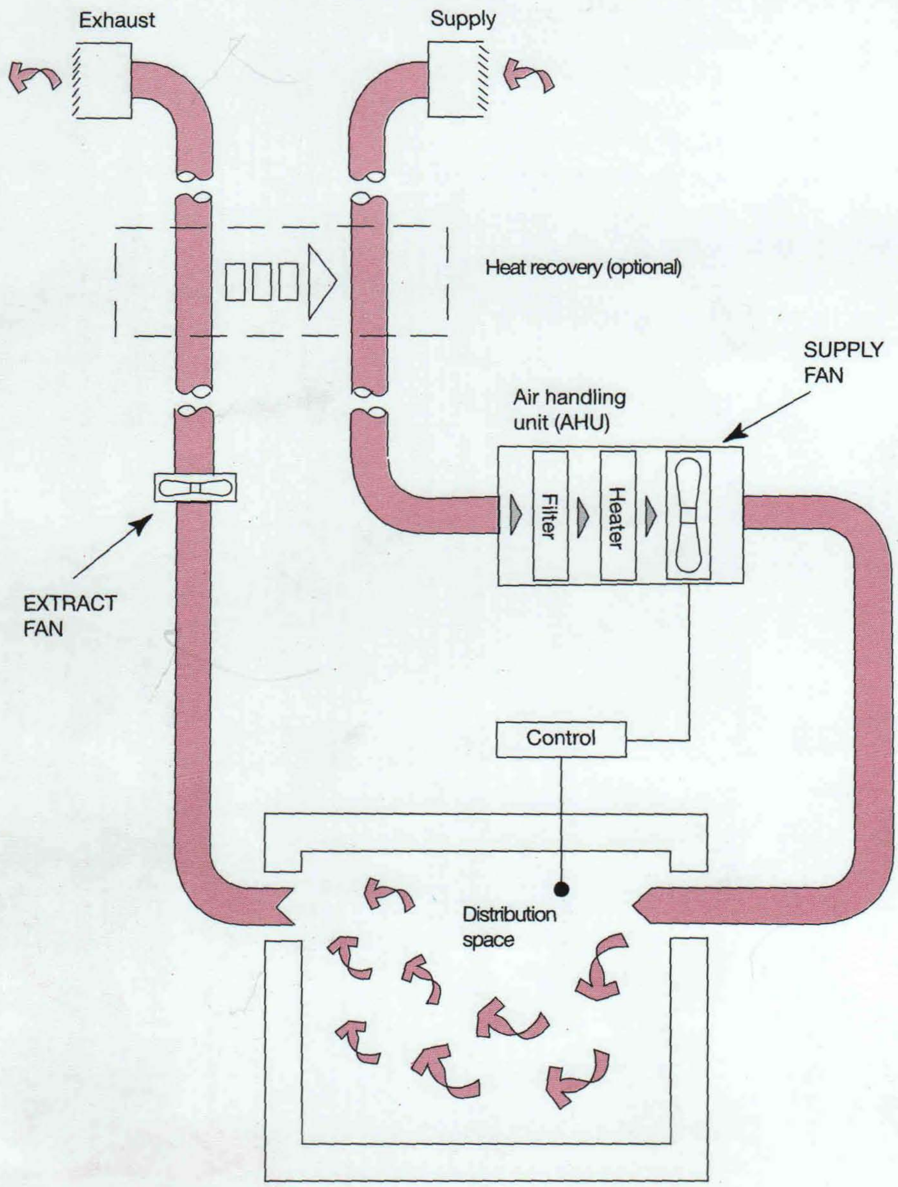
GOOD PRACTICE GUIDE 257

Energy-efficient mechanical ventilation systems



Key points for installers, clients and specifiers

Good design of mechanical ventilation systems can:

- **significantly reduce running costs**
- **improve system reliability**
- **reduce carbon emissions**
- **reduce life cycle costs**

Fan Manufacturers Association

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BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

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BRECSU and the Fan Manufacturers Association (FMA) would like to acknowledge the work of the Welsh School of Architecture and the CIBSE Mechanical Ventilation Task Group in preparing this Guide.

1 INTRODUCTION

Energy-efficient mechanical ventilation (MV) can often be the best solution to ensure minimum fresh air requirements and effective pollutant removal.

Energy use for MV is often overlooked, but can be substantial – in mechanically ventilated offices, fans and pumps typically use as much electricity as lighting.

Designing MV systems with energy efficiency in mind can provide:

- between 5% and 15% savings in running costs for no increase in capital cost (see example 1 on page 7)
- up to 70% reduction in running costs for 20% increase in capital cost with a five-year payback (see example 2 on page 8)
- reduced overall carbon dioxide (CO_2) emissions
- long-term reliability.

Designing with energy efficiency in mind can also benefit installers through:

- satisfied customers
- increased turnover.

PRINCIPLES

MV systems consume energy through the operation of fan motors. The amount of energy used depends on the pressure in the system as well as the volume of air transported. Energy is saved if:

- the pressure drop can be reduced
- an efficient fan is selected
- excess supply of air is avoided.

This document describes a typical MV system, then looks at the three factors in turn.

In designing MV systems it is essential to ensure that the building is airtight so that the system can operate as efficiently as possible.

Overall system efficiency can be expressed in terms of the specific fan power (SFP). The SFP is defined as the installed motor power of all the fans in the air distribution system, divided by the design airflow rate. It is expressed in terms of kW/(m^3/s) or W/(l/s). An efficient system has a low SFP. Table 1 enables the performance of MV systems to be assessed in terms of energy efficiency. For volume flows less than 1 m^3/s the SFP would not normally be less than 1 kW/(m^3/s) due to the inefficiencies of small fans.

It is recommended that the specific fan power should be included in the specification brief and checked at commissioning.

	System energy efficiency		
	High	Medium	Low
Specific fan power kW/(m^3/s)	<1.5	1.5-4.0	>4.0

Table 1 Specific fan power performance

This publication is aimed at:

- ***installers – to help them explain to their clients the benefits and implications of specifying energy-efficient systems***
- ***clients and specifiers – to help them specify energy-efficient systems to their installers.***

2 THE MAIN SYSTEM COMPONENTS

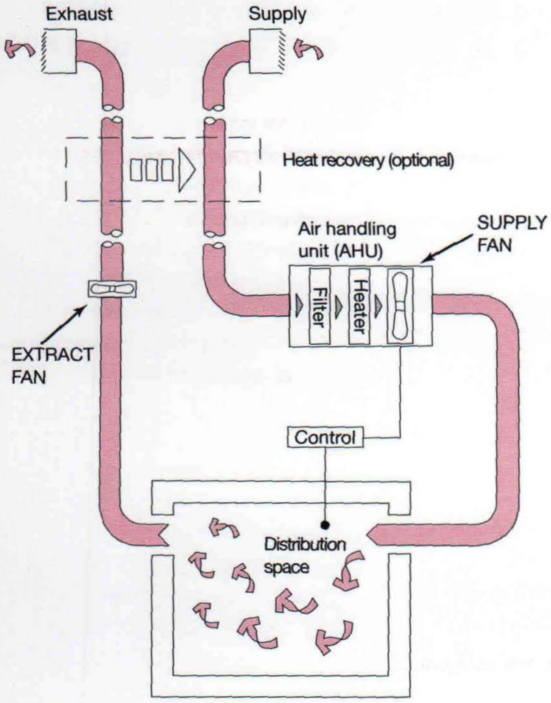

Figure 1 Mechanical ventilation system components

The main components of an MV system are shown in figure 1.

MV systems take in 'fresh air' through louvres at high or low level. The supply air intake is often at high level because air at low level is generally considered to be more polluted.

Ductwork is used to distribute air through the building. This is where a major part of the system pressure drop and the contribution to fan electricity costs occur, typically 40-50% of the total (figure 5, page 8).

The supply air handling unit (AHU) includes air filters, a heater battery and a fan. The air filters normally account for another large proportion of the system pressure drop.

If air-conditioning is being supplied, cooling coils and humidification plant will also be included.

The amount of sound attenuation required is dependent upon the velocity of the system, ie the speed that air travels through the equipment and distribution ductwork. The higher the system velocity the more noise is generated.

Diffusers are used to deliver air to the ventilated space either at high or low level. The exhaust air is usually extracted from the room at high level.

The extract AHU normally consists of just a fan, but it may include a filter if air is to be recirculated. Heat recovery is sometimes employed to preheat or precool the supply air. Air is exhausted to the outside, again usually at high level.

The system is controlled to either run at predetermined periods or in direct response to the comfort/occupancy requirements of the space.

3 SELECTING AN EFFICIENT SYSTEM

1 REDUCING THE PRESSURE DROP

Location of the AHU

A major design issue, when considering the system pressure drop, is where to locate the AHU. The AHU should be as close as possible to the ventilated space, in order to minimise the length of the ductwork run.

Choosing a system velocity

Ductwork should have as large a cross-sectional area as possible to produce low-velocity systems with low pressure drops minimising energy use.

The first choice to be made in designing a system is what system velocity to opt for. Table 2 summarises the pros and cons of each system.

- **Low velocity** – the AHU face velocity would typically be less than 2 m/s with the main duct velocity being 3 m/s.
- **Medium velocity** – the AHU face velocity would typically be 2-3 m/s with a main duct velocity 5 m/s.
- **High velocity** – the AHU face velocity would typically be greater than 3 m/s with the main duct velocity 8+ m/s.

Work with the design team to ensure sufficient space is provided for horizontal/vertical ducting, and integrate the distribution of ductwork with the building structure to avoid complex routeing.

Velocity	Advantages	Disadvantages
Low	Low fan power Low noise	Higher capital cost More space
Medium	Lower capital cost Requires less space	More fan power Increased noise
High	Least capital cost Least space	High fan power High noise

Table 2 Advantages and disadvantages of each system

SELECTING AN EFFICIENT SYSTEM

Ductwork design

Good duct design should achieve air flow which is as laminar as possible throughout the ductwork run to reduce the pressure drop and hence the fan power and noise.

> Laminar flow means the air is being transported in as smooth a manner as possible with little or no turbulence.

When designing ductwork:

- minimise changes to the direction of flow
- where possible, allow 2-3 diameters of ductwork either side of components before changing direction
- use radius bends as opposed to right-angled bends
- use Y-junctions in preference to T-junctions
- use turning vanes wherever appropriate (see figure 2)
- in rectangular ductwork, ensure the aspect ratio is as near to unity as possible.

For further information on efficient ductwork design see the 'Fan Application Guide' produced by the Fan Manufacturers' Association (FMA).

Filtration

There are three main types of filters.

- **Low-efficiency (roughing)** – this category includes disposable panel filters, filter pads, washable filters and automatic roll filters.
- **Medium/high-efficiency (secondary)** – this type includes bag filters, electrostatic filters and deep pleated filters.
- **Very-high-efficiency** – these include high-efficiency particulate air (HEPA) filters and ultra-low-penetration air (ULPA) filters.

In conjunction with the three main filter types there are also special filters, for instance carbon filters which are used for odour removal.

Filters should be selected to achieve the particle extraction effectiveness necessary for the lowest pressure drop, to minimise overall running costs.

Key points when selecting a filter:

- ensure the flow entering the filter is laminar
- make the filter surface area as large as possible
- install a manometer across each filter bank to monitor the pressure drop and to ascertain when filters need changing
- fit access doors for easy filter changing.

More information can be obtained from the HEVAC Association's document 'Guide to Good Practice: Air Handling Units' (see page 11).

Attenuation

In most systems the principal source of noise is the fan. Attenuation may be required to reduce the noise to acceptable levels.

Sound attenuators can be divided into two categories.

- **Reactive** – these silencers consist of an expansion chamber with interconnecting pipes. When a sound wave arrives at this discontinuity only part of the sound is transmitted further.
- **Resistive** – there are many types of resistive silencers, the most common form consisting of rectangular ductwork sections containing splitters of acoustically absorbent infill.

Key points:

- don't mount silencers close to fan outlets as this can affect fan performance
- minimise any increase in air velocity through splitters.

Extra information can be found in the FMA's 'Guide to Fan Noise and Vibration' (see page 11).

Other components

The system pressure drop is also increased by heater batteries, dampers, louvres and air terminals. Care should be taken in the selection of these components to minimise the pressure drop.

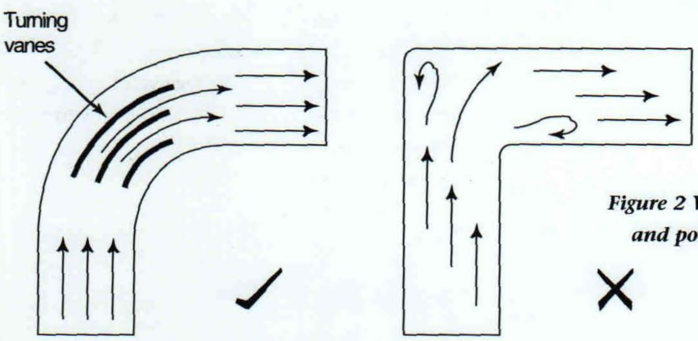

Figure 2 Well-designed and poorly designed bends

LOCATION OF SUPPLY/EXTRACT LOUVRES

- ***Separate the supply and extract louvres to avoid short circuiting.***
- ***Avoid pollution to the supply air from:***
  - ***flues***
  - ***traffic***
  - ***toilet extracts***
  - ***wet cooling towers***
  - ***kitchen extracts.***
- ***Locate intake louvres away from noise-sensitive spaces.***

SELECTING AN EFFICIENT SYSTEM

2 SELECTING AN EFFICIENT FAN

There are four main types of fan.

- **Centrifugal** – air enters at right angles to the outlet.
- **Axial** – air enters and exits axially giving a straight-through configuration.
- **Propeller** – an elementary form of the axial fan but with the impeller mounted in a diaphragm.
- **Mixed flow** – a combination of the axial and centrifugal impellers with a mixture of axial and radial discharge.

The most efficient fan should be selected by comparing the input power of alternative fans at the specified duty point of flow and static pressure.

A margin, known as the contingency, is also usually added on to the calculated pressure drop to account for unforeseen duct runs and dirty filters. This can lead to a higher than expected flow if the actual pressure drop is lower than estimated, as is often the case. Therefore:

- ensure the contingency is only added once
- limit the contingency to 10% or less.

Key points when selecting a fan are as follows.

- Select a fan with an adjustable performance, rather than use dampers to limit the flow.
- Consider the use of variable speed drive (VSD) controlled fans to assist in balancing the system.
- If using VSD-controlled fans then consider the use of direct drive motors to avoid pulley losses.
- When fan selection is left to the manufacturer, ensure that high efficiency is specified.
- Backward-bladed centrifugal fans are generally more efficient and should be used in preference to forward-curved above flow rates of 2 m^3/s.
- Ensure the flow is laminar at the fan inlet/outlet (see figure 3).
- Ideally, allow 4-5 diameters of ductwork either side of the fan before changing direction.

Further information about selecting and installing an efficient fan can be obtained from the FMA's 'Fan Application Guide' (see page 10).

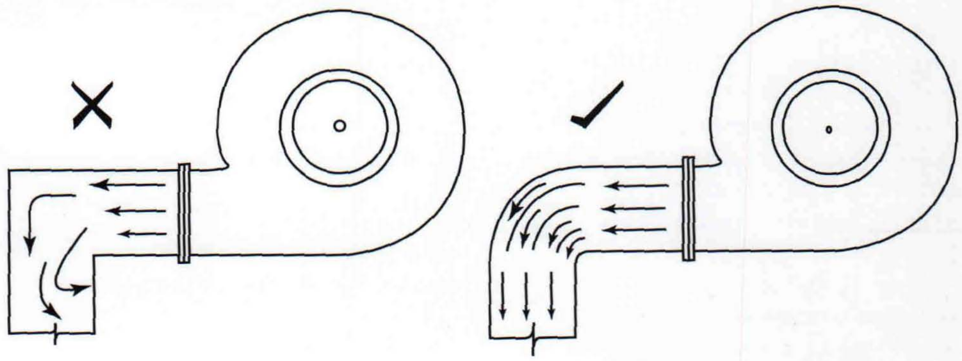

Figure 3 An example of improved handling and design at the fan discharge

SELECTING AN EFFICIENT SYSTEM

3 DEMAND-CONTROLLED VENTILATION

Increased efficiency can be achieved by reducing the volume of air supplied according to the requirement of the space. This can be accomplished through:

- varying the volume of air through the ventilation system (VAV)
- controlling the operation of the fan according to occupancy in both VAV and constant air volume (CAV) systems.

What to measure

After correctly assessing the design ventilation requirements of the space, the supply of air can be controlled according to a number of parameters.

- **CO_2 level** – CO_2 sensors are useful in buildings with wide variations in the ventilation requirement for instance, bingo halls, cinemas, theatres, meeting rooms, etc.
- **Temperature** – thermocouples can be used to sense temperature. It may be advantageous to increase the supply of air, when conditions are favourable, to take advantage of free cooling.
- **Humidity** – humidistats can be used to sense the relative humidity enabling fresh air to be supplied when internal humidity levels are too high.
- **Occupancy** – passive infrared (PIR) sensors can be used to switch off systems when rooms are not occupied.

How to control the fan

There are two main options for controlling the volume of air supplied by the fan.

- **Variable speed drives** – this technique varies the fan performance by reducing the running speed, usually using variable voltage controllers or variable frequency controllers (inverters).
- **Inlet guide vanes** – this method employs special adjustable vanes in the air stream entering the fan. This technique is less efficient than VSD control and is therefore not recommended.

There are two main alternatives for controlling the operating period of the fan.

- **Manual on/off controls** – these are usually best avoided as users frequently forget to use them to switch plant off.
- **Time switches** – clocks can be used to control the operating time of the plant according to the occupancy schedule of the space.

Further information can be obtained from the DETR's General Information Report 41 'Variable flow control' (see page 11).

4 EXAMPLES OF RUNNING COST SAVINGS

EXAMPLE 1 – SAVINGS AT NO INCREASED CAPITAL COST

Figure 4 shows the electricity costs in a typical system compared to a well-controlled good practice system.

A 10% reduction in annual electricity costs is achieved by the appropriately selected and controlled good practice system, for no increase in capital cost.

Notes:
The good practice system has a correctly selected fan operating at an efficiency of 75% compared to 70% for the typical system.

The good practice system is well controlled, operating for the optimum period of time.

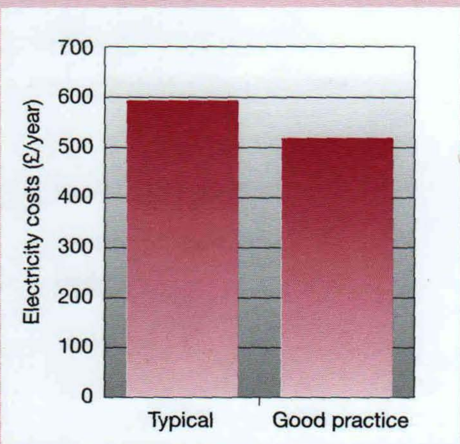

Figure 4 Electricity costs due for each system

EXAMPLES OF RUNNING COST SAVINGS

EXAMPLE 2 – BENEFITS OF LOWERING THE SYSTEM VELOCITY

Figures 5 and 6 illustrate the running and capital costs for systems with different design air velocities. They show how running costs are reduced for low-velocity systems and how some components become more expensive, but others become cheaper. The benefits of the energy-efficient (low-velocity) system compared to the 'standard' (medium-velocity) system include:

- 70% reduction in electricity costs
- extra capital cost recovered in less than five years.

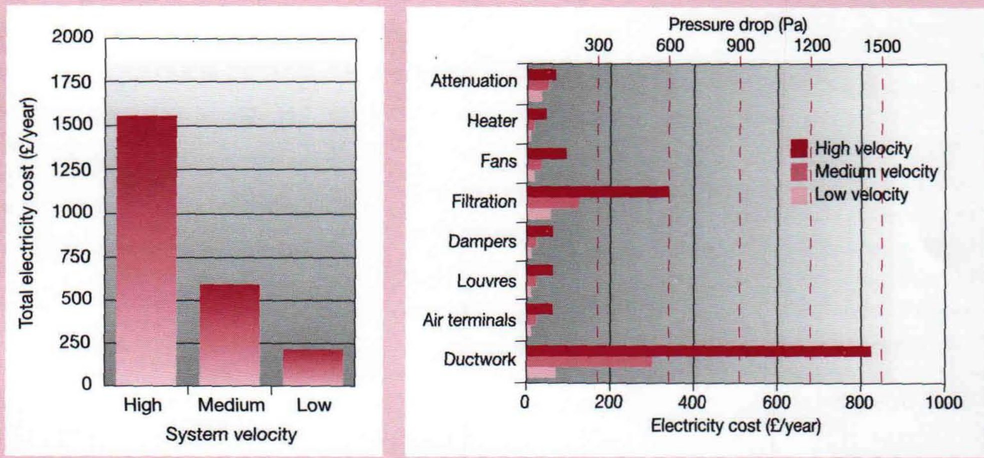

Figure 5 Electricity costs due to the pressure drop across the systems

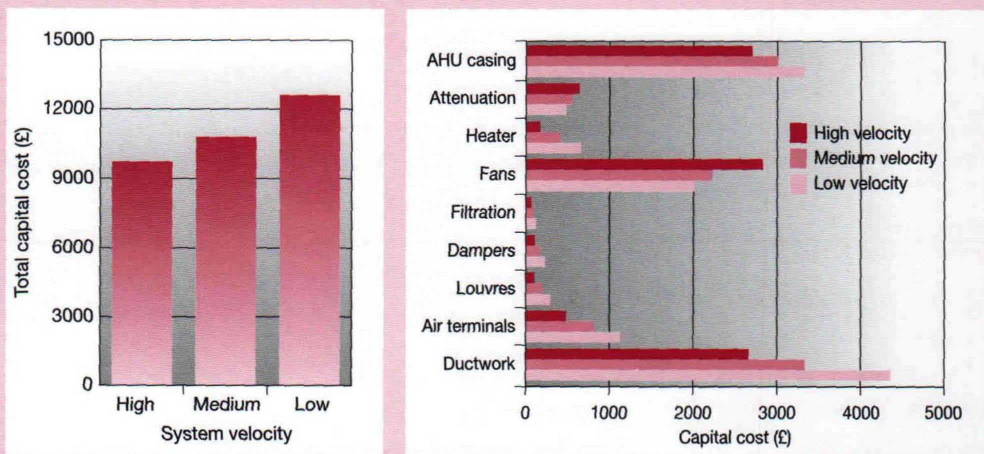

Figure 6 Capital costs of the systems

NOTES:
All systems are supplying 2 m^3/s of air.
All systems are supplied by a centrifugal fan operating at 70% efficiency.
Pulley efficiency: 95%, motor efficiency: 80%, electricity cost: 5.0p/kWh, annual run time: 3000 hours
Sound levels less than 40 dBA for high-, medium- and low-velocity systems.

5 RELATED ISSUES

AIR DISTRIBUTION

The delivery of air by an MV system should:

- achieve a good ventilation effectiveness (ie avoid short circuiting of air between supply and extract)
- avoid draughts to the occupants (ie ensure that the air is at a satisfactory speed and temperature in relation to occupant comfort).

There are two main ways of distributing air within the ventilation space.

- **Displacement (low-level supply/high-level extract)** – air, supplied at low level, is displaced upwards through heat gains (see figure 7). The main advantages of this system are that, due to stable upward air movement, higher supply temperatures can be tolerated, so lower volumes of air need to be supplied.
- **Mixing (high-level supply/high-level extract)** – air is both supplied and extracted at ceiling height (see figure 8). Supply air is mixed by entrainment with air in the space. The main advantage of this type of system is that it can deal with high cooling loads.

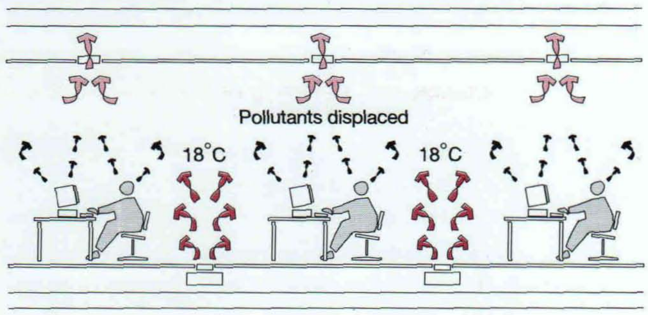

Figure 7 Low-level supply/ high-level extract

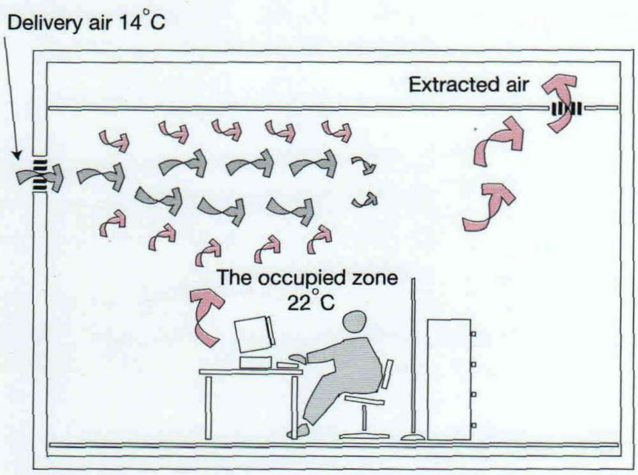

Figure 8 High-level supply/ high-level extract

HEAT RECOVERY

Heat recovery becomes economic when the value of the recovered heat outweighs the increase in fan capital and running costs, as well as the heat recovery equipment cost.

Key points

- The viability of heat recovery increases as the number of air changes per hour (ach) increases.
- Heat recovery increases in cost-effectiveness the higher the temperature difference between supply and extract.
- The length of the heating/cooling season and the operating times influence heat recovery.
- Heat recovery can increase the overall pressure drop and subsequent fan power used by 50%.
- Double accumulators offer high heat recovery efficiencies and lower pressure drops.
- Heat recovery is most efficient when supply and extract streams can be designed to be adjacent.
- Heat recovery can still be considered when supply and extract ducts are not adjacent through the use of a run-around coil.

Table 3 shows the different characteristics of the four main heat recovery systems used in the UK. For further information see the CIBSE Guide B.

	Efficiency (%)	Pressure drops (Pa)	Separate air stream	Adjacent ducts needed
Run-around coil	40-50	200-500	Yes	No
Plate heat exchanger	40-70	250-500	Yes	Yes
Thermal wheel	60-85	200-500	No	Yes
Double accumulator	85-95	150-200	No	Yes

Table 3 Characteristics of heat recovery equipment

COMMISSIONING CHECKLIST

1) ***Carry out building pressurisation test.***
2) ***Check ductwork is as specified in the design.***
3) ***Ensure ducts are sealed.***
4) ***Ensure the volume flow rate is appropriately measured.***
5) ***If necessary, adjust the fan characteristic to ensure it is supplying the required amount of air, in consultation with the fan manufacturer.***
6) ***Check specific fan power is in line with the specification.***
7) ***Re-check the system after one year of operation.***

6 FURTHER INFORMATION

FURTHER INFORMATION

There are many other sources of more detailed information.

Air Infiltration and Ventilation Centre

'AIVC Ventilation Guide'

The purpose of the Air Infiltration and Ventilation Centre's guide is to review ventilation in the context of achieving energy efficiency and good indoor air quality. It is primarily concerned with providing an introduction to the topic and encapsulates the knowledge and experience derived from experts in all the participating countries.

Sovereign Court, Warwick University Science Park, Coventry CV4 7EZ
Tel 01203 692050. Fax 01203 416306

Building Services Research and Information Association (BSRIA)

'Air Filters – A Selection Guide'

The guide assists air handling manufacturers, designers, specifiers/consultants, installation and maintenance engineers in the selection and use of air filters in ventilation and air-conditioning systems in the heating and ventilation industry. Published by BSRIA it provides more detailed information on selecting the appropriate filter for the given application.
(ISBN 0 86022 290 X)

Old Bracknell Lane West, Bracknell, Berks RG12 7AH
Tel 01344 426511. Fax 01344 487575

CADDET

'Learning from Experiences with Industrial Ventilation'

This book demonstrates the practical aspects of energy conscious design. It provides background information which assists the decision maker in understanding the concepts behind different approaches. It is published by Caddet and distributed in the UK by the Energy Technology Support Unit (ETSU).
(ISBN 90-72647-04-1)

Energy Efficiency Enquiries Bureau, Harwell, Oxfordshire OX11 0RA
Tel 01235 436747. Fax 01235 433066

Chartered Institution of Building Services Engineers

CIBSE Guide Volume B 'Installation and Equipment Data'

Sections B2 and B3 cover ventilation and air-conditioning in detail. They describe the ventilation requirements of different buildings, together with the systems, equipment and controls used to satisfy the requirements. (ISBN 0 900953 30 6)

Delta House, 222 Balham High Road, SW12 9BS
Tel 0181 675 5211. Fax 0181 675 5449

Eurovent Certification Company SCRL

EUROVENT Certified Performance – The Mark of Confidence

The EUROVENT certification programme utilises European and International standards to create a common set of criteria for rating fans and other products.

EUROVENT Certification Company SCRL
15, rue Montergueil, 75001 Paris.

Fan Manufacturers' Association

'Fan Application Guide'

Produced by the Fan Manufacturers' Association this guide covers the basic knowledge required, together with the pitfalls to avoid, in order for an installation to do what it was designed for.

'Fan and Ductwork Installation Guide'

This technical guide reports measurements of the effects of commonly used ductwork fittings on fan performance.

FURTHER INFORMATION

'Guide to Fan Noise and Vibration'
This guide provides information on noise and vibration issues relating to fans and fan installations. The information ranges from fundamental definitions to practical advice.

HEVAC 'Guide to Good Practice: Air Handling Units'
This publication offers advice on the points to observe and pitfalls to avoid when choosing an AHU. Published by the Federation of Environmental Trade Associations.

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DETR ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. Contact details are given on the back page.

General Information Report

41 Variable flow control

Good Practice Guide

71 Selecting air conditioning systems. A guide for building clients and their advisers

New Practice Final Report

106 The Elizabeth Fry Building, University of East Anglia – feedback for designers and clients

The Department of the Environment, Transport and the Regions' Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

For further information on:

Buildings-related projects contact:
Enquiries Bureau

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Industrial projects contact:
Energy Efficiency Enquiries Bureau

ETSU
Harwell, Oxfordshire
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Tel 01235 436747
Fax 01235 433066
E-mail *etsuenq@aeat.co.uk*

Internet **BRECSU** – http://www.bre.co.uk/brecsu/
Internet **ETSU** – http://www.etsu.com/eebpp/home.htm

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting etc.